Data Assimilation of SMAP Observations and the Impact on Weather Forecasts and Heat Stress

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3rd SMAP Applications Workshop

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Assimilation of SMAP observations into the NOAH Land Surface Model: Impact of SMAP observations on weather forecasts in a coupled simulation environment

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NASA SPoRT

Objectives

Level 1 brightness temperature and/or Level 2 soil moisture products from SMAP will be assimilation into the Noah Land Surface Model (LSM) using an Ensemble Kalman Filter within the Land Information System (LIS) framework. LIS runs of the Noah LSM assimilating SMAP data will be used as surface boundary conditions to initialize coupled LIS-WRF (Weather Research and Forecasting) model forecasts. We will assess the impacts of the assimilated SMAP data on the subsequent weather forecasts.

Team Membership

Clay Blankenship, Jonathan Case, and Bradley Zavodsky, NASA Short-term Prediction Research and Transition (SPoRT) Center; SMAP Contact: Molly Brown

Methodology/Approach

- assimilate and validate SMOS data
- assimilate simulated SMAP data
- assimilate real SMAP data
- assess the impacts of the assimilated SMAP data on the subsequent weather forecasts.
- make the LIS output products available in real-time to NWS partners for initialization their local forecast models.

Status

- **Assimilated SMOS Level 2 UDP retrievals into Noah 3.2 using LIS**
  - **Successfully produces model increments**
  - **Biases are large (obs are dry relative to the Noah model most of the time, also dynamic range of obs is larger)**

Schedule and Issues

- **Now implementing bias correction (CDF adjustment) for SMOS**
- **Future plans**
  - **Implement for high-resolution domains (finer than observation scale)**
  - **Implement with SMAP simulated data**

Short-term Prediction Research and Transition (SPoRT)

Mission: Transition unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale.

- Close collaboration with numerous WFOs and National Centers across the country
- SPoRT activities began in 2002, first products to AWIPS in 2003
- Co-funded by NOAA since 2009 through "proving ground" activities
- Proven paradigm for transition of research and experimental data to "operations"

Benefit:

- Demonstrate capability of NASA and NOAA experimental products to weather applications and societal benefit
- Take satellite instruments with climate missions and apply data to solve shorter-term weather problems

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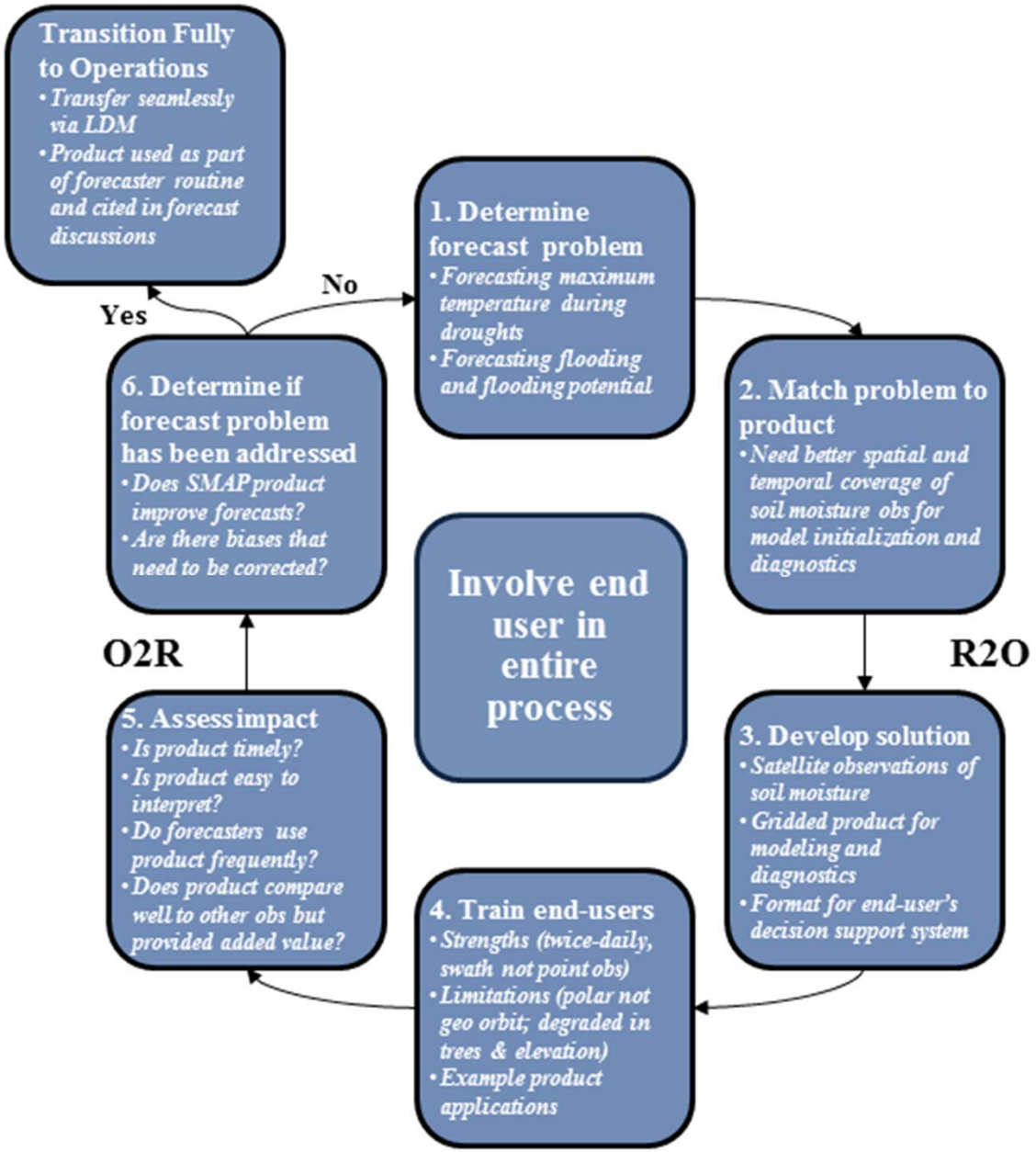
SPoRT R2O/O2R Paradigm



- Match forecast challenge to data/product
- Develop solution/ demonstrate in "test bed" environment
- Integrate successful products into end user's decision support system
- Create product training
- Perform targeted product assessments
- Maintain interactive partnership with end user throughout process
- Need local end user advocate

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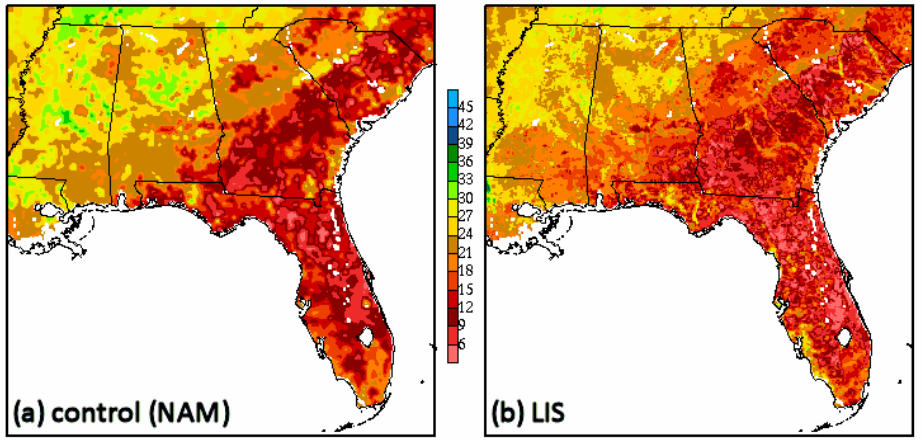
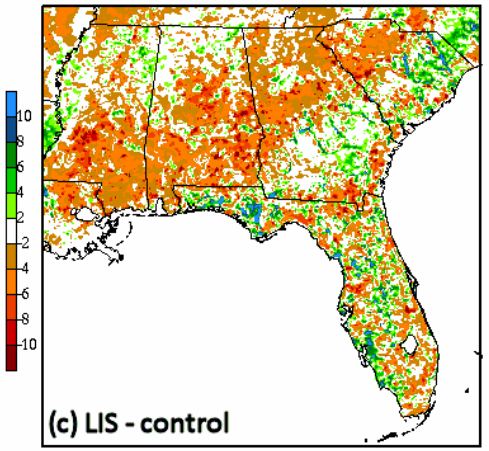
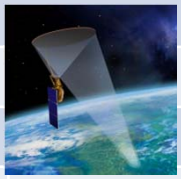
Motivation for Using SMAP Data

- **Proper characterization of real-time, local-scale (< 10 km) soil moisture will aid decision makers**
- **SMAP will offer a blended active/passive product with a resolution of around 9 km that will provide an optimal balance between resolution and accuracy**

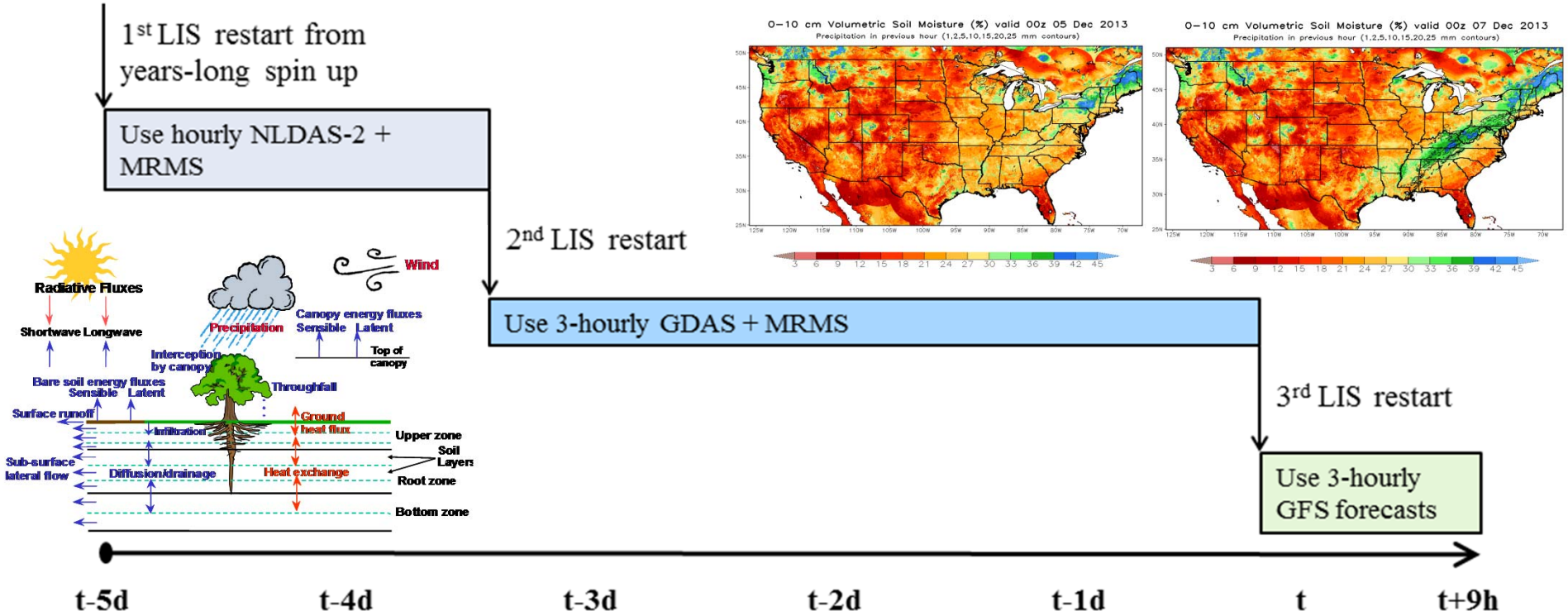




Name	SMOS Soil Moisture and Ocean Salinity	SMAP Soil Moisture Active/Passive	
Agency	ESA	NASA	
Launch	2009	Nov. 2014	
Orbit	Polar	Polar	
Sensor Type	Passive	Active	Passive
Frequency	1.4 GHz (L-band)	1.2 GHz	1.41 GHz
Resolution	35-50 km	>=1-3 km	36 km
Accuracy	4 cm^3/cm^3	6 cm^3/cm^3	4 cm^3/cm^3



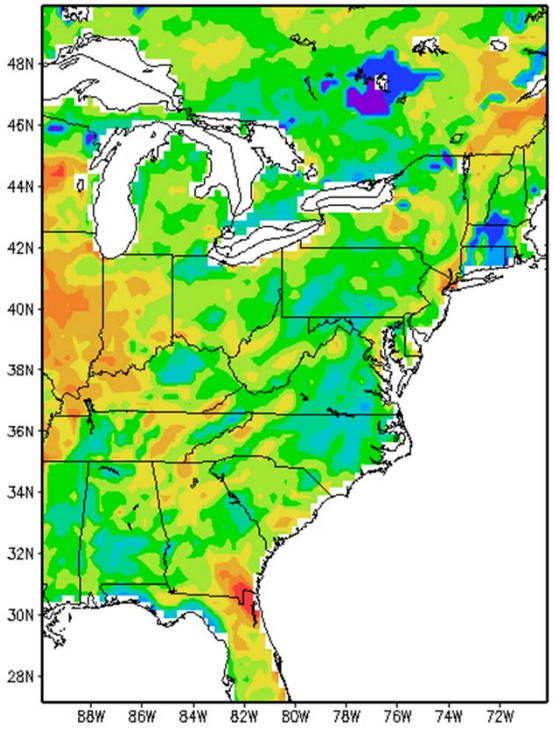
Operational SPoRT Land Information System (LIS)



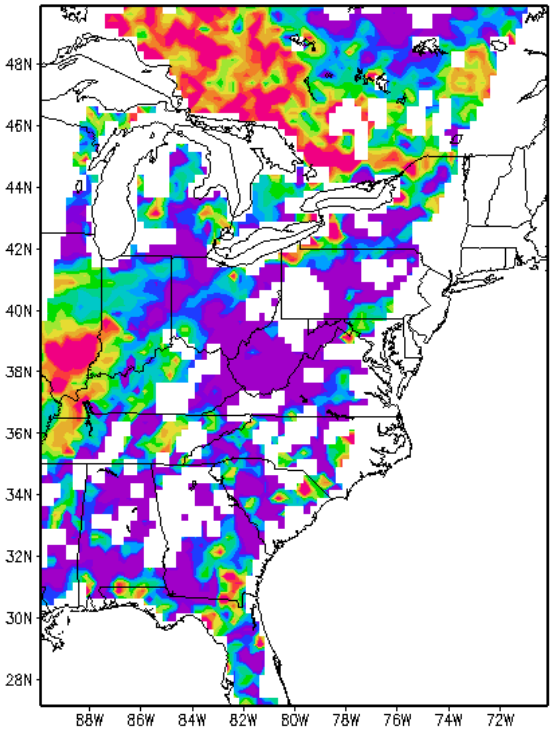
- NASA LIS used to perform long-term integration of Noah Land Surface Model (LSM) updated in real-time
  - Precipitation forcing: NLDAS-2, Multi-Sensor, Multi-Radar (MRMS), and GFS forecast
  - Vegetation coverage/health: Green Vegetation Fraction (GVF) from MODIS (VIIRS 2014)
  - Forecast data allows use of latent observations while retaining their impact on later cycles
- Assimilation of soil moisture during 2nd LIS restart should give even more accurate LSM soil moisture fields
- Used for situational awareness and local modeling

Soil Moisture Data Assimilation

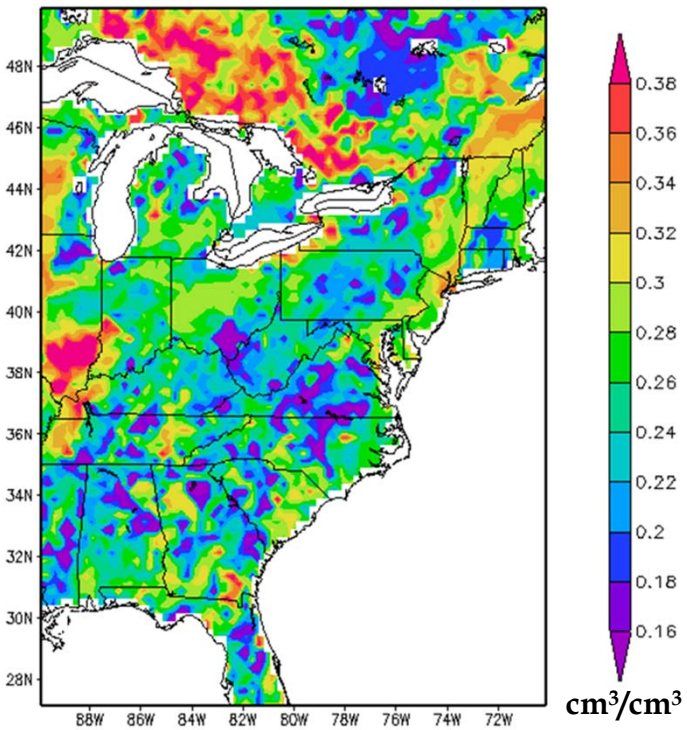
LIS soil moisture: 0Z 5 June



SMOS Obs 23Z 4 June



After assimilation: 3Z 5 June



- **Assimilating SMOS Level-2 soil moisture observations into LIS using built-in Ensemble Kalman Filter**
  - **Data are quality controlled for coastline, rain, vegetation, RFI, and snow cover**
  - **Pattern of SMOS observations appears in analysis with maxima and minima aligned; currently tuning so analysis doesn't look so much like the observations**
- **Sample SMAP L2 data available to Early Adopters will be tested with this module**

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Placeholder for new SMOS assimilation results from Clay

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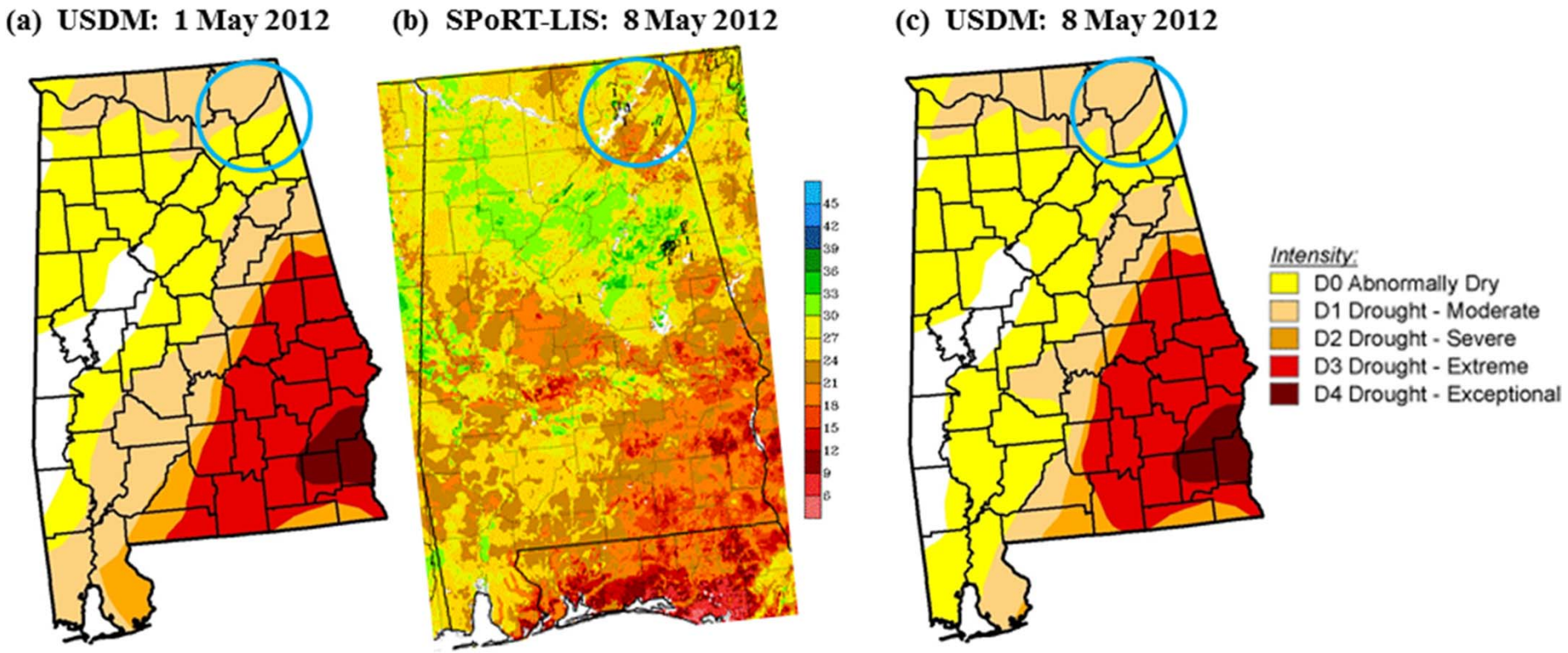
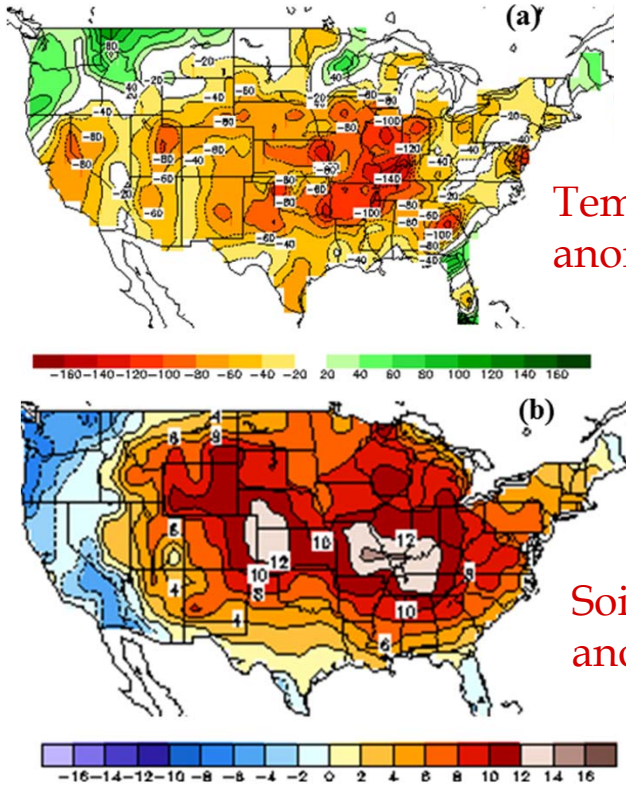
Applications: Drought Monitoring



- **Soil moisture from SPoRT LIS has been used by NWS forecasters to refine drought indices on the county scale**
- **Soil moisture and GVF output from LIS could also be applied to situational awareness and forecasts of red flag warnings and potential for fires**

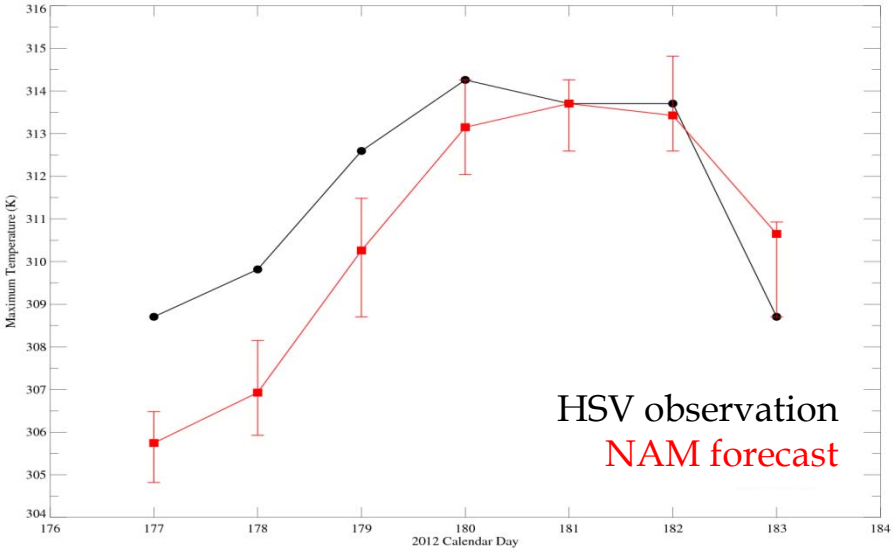
Applications: Extreme Heat

- **Extreme heat causes more deaths annually in the U.S. than severe weather; small T and RH differences can have large impact on human health**
- **NWP models tend to underestimate daytime air temperatures when the modeled soil moisture is higher than the true conditions**
- **Initializing models with SMAP data should result in improved maximum temperature forecasts by providing more accurate soil moisture**



Temperature anomalies

Soil moisture anomalies



Forecast temperatures with verification, 26 June - 2 July 2012

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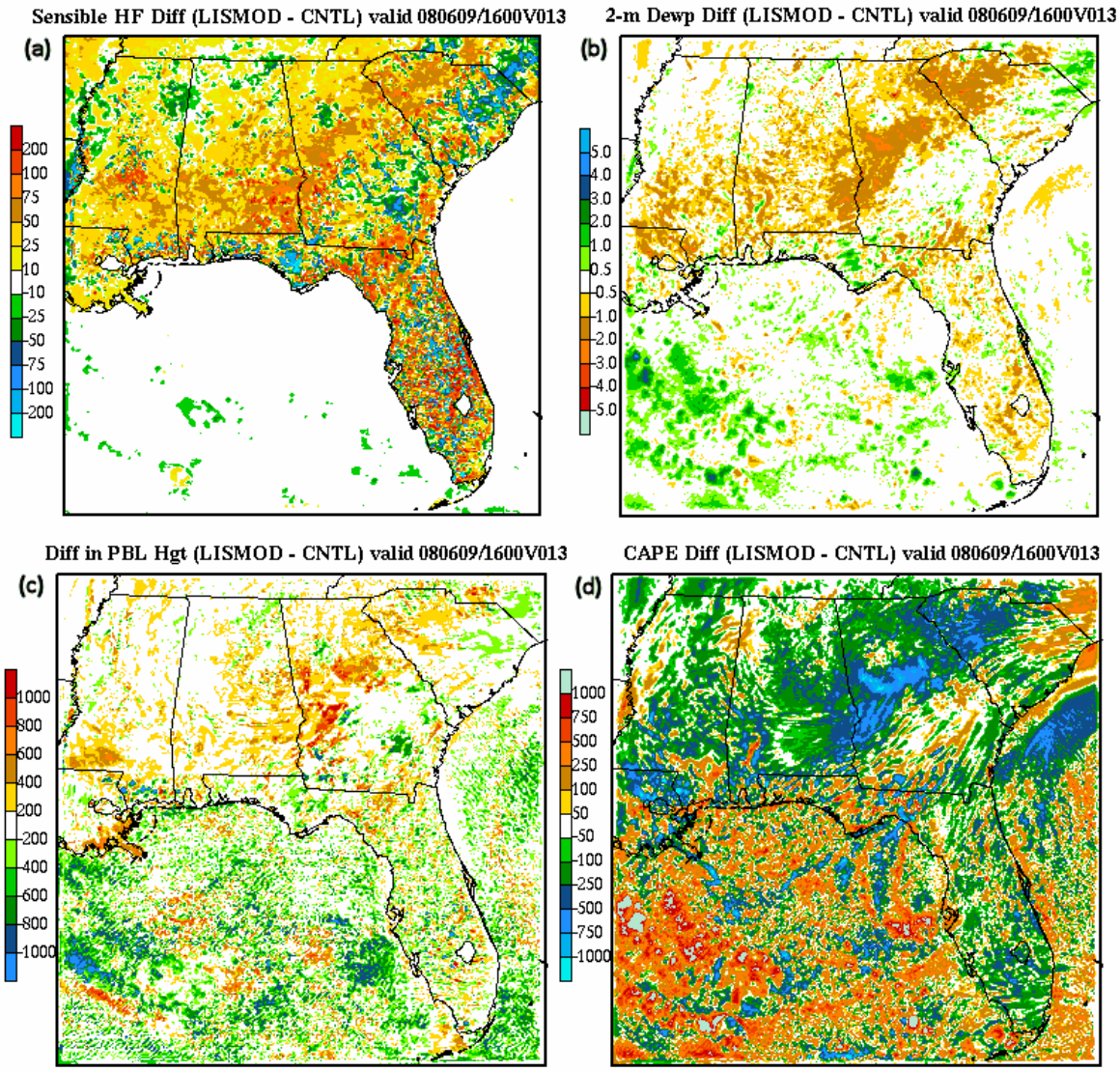
Applications: Convective Initiation



- Gradients in soil moisture and heat fluxes can generate differential heating boundaries that initiate convection in weakly-forced regimes
- Initializing models with higher-resolution LIS data result in more accurate fields used to predict convection (figure at left)
- Convective summer storms can generate heavy rain (flash flooding), strong winds, and lightning (fires)

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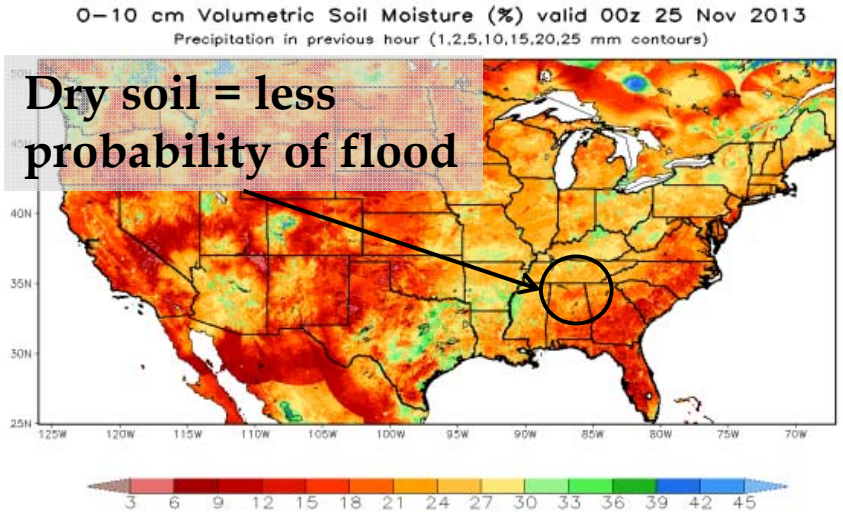
Applications: Flood & Water Borne Disease

- SPoRT LIS data used by NWS forecasters to issue flood guidance
- Flooded areas and areas with high soil moisture can be breeding grounds for mosquitoes which may carry a number of infectious diseases
- High-resolution, real-time soil moisture fields from LIS could be used to identify areas at highest risk for flooding

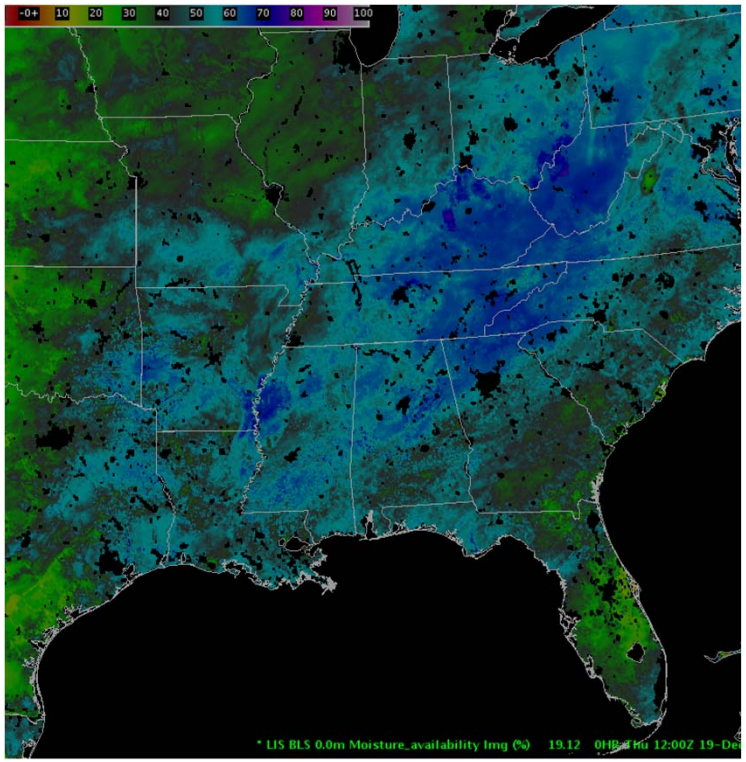


CULLMAN/MARSHALL/DEKALB COUNTIES WILL BE MOST LIKELY TO SEE THESE 3+ INCH TOTALS. WITH 3 AND 6 HR FLASH FLOOD GUIDANCE OVER 2 INCHES ACROSS THE CWA...AND ***DRY SOILS INDICATED IN THE NASA LIS DATA***...THIS SUGGESTS WE WILL BE ABLE TO HANDLE MUCH OF THIS RAINFALL SINCE IT WILL BE OCCURRING OVER THE ENTIRE DAY. THAT BEING SAID...WATERWAYS WILL LIKELY SEE SOME GOOD RISES AND ISOLATED FLOODING PROBLEMS MAY DEVELOP. LOCATIONS THAT SEE ANY BURSTS OF HEAVY RAINFALL WILL HAVE TO BE MONITORED CLOSELY...ESPECIALLY SINCE FALL LEAVES ON THE GROUND COULD IMPACT DRAINAGE.

Summary

- SPoRT produces real-time LIS soil moisture products for situational awareness and local numerical weather prediction over CONUS, Mesoamerica, and East Africa formatted for end-user decision support systems
- Currently interact/collaborate with operational partners on evaluation of soil moisture products
  - Drought/fire
  - Extreme heat
  - Convective initiation
  - Flood and water borne diseases
- Initial efforts to assimilate L2 soil moisture observations from SMOS (as a precursor for SMAP) have been successful
- Active/passive blended product from SMAP will be assimilated similarly and higher spatial resolution should improve on local-scale processes

Soil moisture from SPoRT-LIS in NWS AWIPS II Decision Support System



Acknowledgments

- Work is supported by Tsengdar Lee of the NASA Science Mission Directorate through SPoRT
- Would like to thank Susan Moran, Vanessa Escobar, and Molly Brown for including us as SMAP Early Adopters and inviting us to present at this workshop

- Details on SPoRT's real-time LIS and expected use of SMAP data can be found in
  - Zavodsky, B. T., J. L. Case, C. B. Blankenship, W. L. Crosson, K. D. White, 2013: Application of next-generation satellite data to a high-resolution, real-time land surface model, Earthzine, J. Kart, editor, Institute of Electrical and Electronics Engineers [Available online at http://www.earthzine.org/2013/04/10/application-of-next-generation-satellite-data-to-a-high-resolution-real-time-land-surface-model/.]

and from abstracts presented at AMS Annual Meeting:

- Blankenship et al. (28th Conference on Hydrology; P53)
- Case (26th Conference on WAF/NWP; P162)
- Case et al. (26th Conference on WAF/NWP; J9.4)

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